Irrig Sci (1982) 3: 169–175

Irrigation Science

Effects of Salinity on Germination, Growth and Yield of Cowpea

D. W. West[1] and L. E. Francois

U.S. Salinity Laboratory, USDA, ARS, Riverside, CA 92501, USA

Received March 17, 1982

Summary. Adequate information on salt tolerance is lacking for cowpea (*Vigna unguiculata* (L.) Walp.), a crop grown under both dryland and irrigated conditions. A two-year field plot study was conducted to determine the responses of both the vegetative and dry seed yield of cowpea to a range of soil salinities. Four salinity levels were imposed each year on a Pachappa fine sandy loam (mixed, thermic, Mollic Haploxeralf). Vegetative growth, dry seed yield, and several components of seed yield were measured.

Vegetative yield was decreased more by increasing soil salinity than was dry seed yield. Vegetative growth was reduced 9.0% for each unit increase in electrical conductivity of the soil saturation extract beyond a threshold value of 1.6 dS/m. Dry seed yield was reduced 12% for each unit increase beyond 4.9 dS/m. Fewer pods per plant accounted for nearly all of the seed yield reduction associated with increasing salinity levels.

Germination was significantly reduced when electrical conductivity in sand cultures exceeded 12.0 dS/m.

Cowpeas (*Vigna unguiculata* (L.) Walp.) are widely grown in different parts of the world for different purposes e.g. for dry beans in West Africa (Hall and Dancette 1978; Lush 1979), India (Balasubramanian and Sinha 1976), and the USA (Turk et al. 1980), as a green vegetable in East Africa (Imbamba 1973; Lush 1979) and as a fodder crop for livestock in Australia (Molnar 1961; Russell 1976). They are grown under a wide range of climatic conditions ranging from semiarid to subhumid as a dryland crop (Lush and Rawson 1979) and are reported to have good tolerance to both heat and drought (Rachie and Roberts 1974). While cowpeas are well adapted to drought conditions (Hall and Dancette 1978; Turk and Hall 1980a, 1980b, 1980c; Turk et al. 1980) they also have a high yield potential under irrigation (Turk et al. 1980).

---

[1] Permanent address: Irrigation Research Institute, Department of Agriculture, Tatura, Victoria 3616, Australia

0342-7188/82/0003/0169/$ 01.40

Increasing world demands for food is resulting in increasing demands on soil and water resources. The use of marginal quality waters and soils is increasing and this subjects crop plants to increased salinity. Obtaining satisfactory crop production and irrigation efficiency with these soils and waters requires information on the salt tolerance of crops.

According to Maas and Hoffman (1977), two parameters must be determined to adequately define the salt tolerance of a crop. They are: *1)* the mean value of salinity in the rootzone which, if exceeded, results in decreased yield, and *2)* the rate of yield decline as rootzone salinity increases beyond this threshold value. Most of the studies on the response of cowpeas to salinity (Balasubramanian and Sinha 1976; Imbamba 1973; Ravikovitch and Porath 1967; Russell 1976; Tawfic et al. 1977) only report the effect on vegetative growth. They do not provide sufficient data in terms of the two parameters to adequately describe the salt tolerance. The response of vegetative growth to salinity is often not a reliable guide for predicting seed production (Maas and Hoffman 1977). Since cowpeas are grown for vegetative and seed yield, salt tolerance data are needed for both of these growth components.

The objective of this 2-year plot study was to determine the vegetative and seed yield responses of cowpeas over a range of soil salinities under field conditions. Since seed germination often responds differently to salinity, germination was studied separately in the laboratory using differentially salinized sand cultures.

Materials and Methods

The experiment was conducted in twelve 4.27 m^2 plots that contained Pachappa fine sandy loam (mixed, thermic, Mollic Haploxeralf). Each plot was enclosed by raised concrete borders which extended approximately 75 cm into the soil. The soil in each plot was formed into five flat-top beds on 85 cm centers. All beds were 15 cm high and 15 cm wide. A single row of California Blackeye No. 5 cowpea seed, treated with Arasan and Demosan fungicides, was sown on each bed, 4 cm from the bed shoulder. The plants were spaced 15 cm apart within each row. Tensiometers were installed in each plot at 15 and 30-cm depths to guide irrigation. Irrigations were applied when tensiometer readings for the control treatments reached an average matric potential of – 50 J/kg (– 0.5 bars) at the 15-cm depth.

Prior to the first trifoliolate leaf stage (3 weeks after planting) the plants were irrigated with non-saline tap water containing 0.7 mM $Ca(NO_3)_2$ and 1 mM KNO_3 per liter of water applied. These two salts were added at every irrigation throughout the experimental period to reduce possible effects resulting from influences of salinity on nitrogen fixation which could influence growth or yield. The salinity of the irrigation water was then increased stepwise over a 3-week period, by adding equivalent weights of NaCl and $CaCl_2$, until desired salt concentrations were achieved. The average electrical conductivities of the irrigation water ($\varkappa_i$) for the 2 years were 0.8, 3.3, 5.7 and 10.3 dS/m. These salinity levels were maintained throughout the growing seasons. A 5-cm depth of irrigation water was applied approximately weekly to each plot until harvest. Each treatment was replicated three times.

The electrical conductivity of the saturation extract ($\varkappa_e$) was determined on soil samples taken four times during each growing season. Samples were taken to a depth of 90 cm in 30 cm increments. The average $\varkappa_e$ in the root zone were 1.1, 3.2, 4.3, and 6.9 dS/m in 1980 and 1.1, 5.2, 6.9, and 9.5 dS/m in 1981. These salinities were established within a few weeks after full strength saline irrigations were applied and were maintained throughout the growing season. Salinities were nearly uniform with rootzone depth.

Mature, fully expanded, healthy leaves were sampled from each plot at flowering. Dried and ground samples of these leaves were analyzed for Na, K, Ca, and Mg by atomic absorption spectrophotometry. Cl by potentiometric titration (Brown and Jackson 1955), and P by Molybdovanadate-yellow (Kitson and Mellon 1944).

Plants were harvested 94 days after seeding in both 1980 and 1981. Pods were removed manually from plants at harvest, dried (48 h at 65 °C) weighed, and threshed. Top growth (minus pods) was oven dried (48 h at 65 °C) and weighed. Total number of pods per plant and number of seeds per pod were determined from pods harvested from the middle row of each plot. Seed samples were analyzed for the same elements as leaves plus S by barium chloride precipitation after nitric-perchloric acid oxidation (Shaw 1959) and total N by standard Kjeldahl method.

Root distribution within the soil profile was determined by trenching across each plot to a depth of 90 cm immediately after harvest.

To test germination response of California Blackeye No. 5 at different salinities, four replicates of 25 seeds each were planted in trays of fine, washed sand. The sand had been premoistened with solution containing equivalent weights of NaCl and $CaCl_2$ to produce salinity levels ($\varkappa_{sw}$) of 0, 4, 8, 12, 16 and 20 dS/m. The trays were placed in a lighted high humidity environment at 29 °C and seed germination was assessed at several times over a period of 13 days.

Results and Discussion

All data for growth or yield have been related to electrical conductivities of saturation extracts of soil samples taken from within the rootzone ($\varkappa_e$) over the growing season. This includes soil samples to a depth of 90 cm, although it was estimated from observations on root distribution that 60 to 70% of the roots were in the top 30 cm of the rootzone. No measurements were made of actual water extraction patterns with increasing depth of soil. Soil samples taken at the time of planting showed $\varkappa_e$ to be low and uniform throughout the profile in all plots, averaging 0.5 dS/m.

The relationship between relative shoot dry weight (minus seed) and mean $\varkappa_e$ for the two years shows a maximum allowable soil salinity of 1.6 dS/m (the threshold value) before growth was decreased (Fig. 1 and Table 1). A linear regression analysis indicated that growth was reduced 9% for each unit increase in average soil salinity greater than 1.6 dS/m. These values coincide closely with data

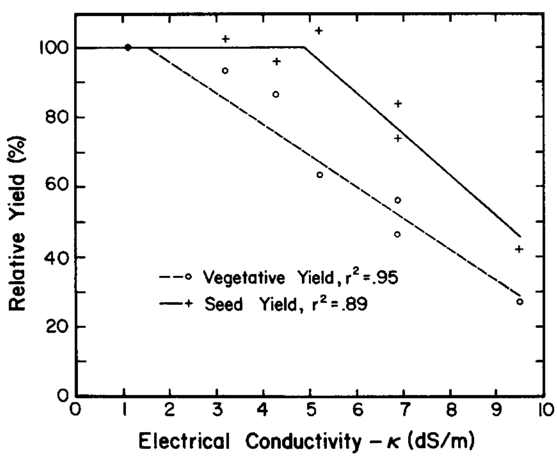

Fig. 1. Vegetative and seed yield response of cowpea to increasing soil salinity

Table 1. Growth and seed yield of cowpea at several soil salinities for two harvest years

Soil salinity ($\varkappa_e$)	Dry plant wt (minus seed)	Dry seed wt	Harvest[a] index	100 seed wt	Number of pods per plant	Number of seeds per pod
dS/m	g/m² (%)	g/m² (%)	%	g (%)	No. (%)	No. (%)
			1980			
1.1	305.3 (100)[b]	255.3 (100)	45.5	19.4 (100)	23.8 (100)	6.98 (100)
3.2	283.2 (93)	260.6 (102)	47.9	19.6 (101)	23.1 (97)	7.79 (112)
4.3	262.0 (86)	245.7 (96)	48.4	19.5 (101)	22.1 (93)	7.53 (108)
6.9	171.5 (56)	190.2 (74)	52.6	18.2 (94)	17.6 (74)	7.29 (104)
L.S.D. (0.05)	38.3	43.7	3.3	NS	4.8	0.70
			1981			
1.1	497.7 (100)	347.9 (100)	41.3	22.5 (100)	27.1 (100)	6.55 (100)
5.2	316.7 (64)	367.1 (105)	53.8	23.5 (104)	30.4 (112)	7.21 (110)
6.9	230.2 (46)	292.0 (84)	55.8	24.9 (111)	23.4 (86)	7.21 (110)
9.5	132.7 (27)	145.9 (42)	52.4	22.9 (102)	15.5 (57)	6.37 (97)
L.S.D. (0.05)	86.6	46.1	8.0	NS	4.4	0.56

[a] Harvest Index = seed weight/total shoot weight × 100
[b] Relative values with relation to controls set at 100% each year

for vegetative growth of the variety 'Caloona' which was harvested prior to flowering and grown over the same range of values of rootzone $\varkappa_e$ (Russell 1976). When our data and ‚Caloona' were combined and analyzed there was a highly significant linear correlation between relative yield and $\varkappa_e$.

The combined data for the two years show a relationship between relative yield of dry beans and mean $\varkappa_e$ where the maximum allowable $\varkappa_e$ is 4.9 dS/m before reduction in yield occurred (Fig. 1 and Table 1). Each unit increase in average soil salinity beyond this threshold resulted in a 12% reduction in dry seed yield. Thus, as with many other crops (Maas and Hoffman 1977), relative dry seed yield was less severely affected than was vegetative growth over the salinity range tested. The threshold salinity is higher and rate of reduction in relative yield slightly less than that calculated from the data of Ravikovitch and Porath (1976). In fitting their data to the model used by Maas and Hoffman (1977), the threshold value lies between 1.2 and 2.1 dS/m and the rate of yield reduction between 14.3 and 17.7% per unit increase in $\varkappa_e$. The values we obtained would rank California Blackeye No. 5 as being moderately tolerant to salinity according to the classes defined by Maas and Hoffman (1977).

Because mean seed yield was less affected than was plant dry matter over the salinity range tested, the harvest index of the plants increased with increasing salinity. The proportion of seed to total top weight changed from 45.5% and 41.3% for the control treatment to 52.6% and 52.4% for the most saline treatment for the 1980 and 1981 growing seasons, respectively (Table 1). Mean seed weight was not significantly affected by increasing salinity, and variation in the number of pods per plant accounted for nearly all of the yield reduction with increasing salinity (Table 1).

Dry seed yield, pod density and seed size in the present experiment were compared with data for the same variety reported for an irrigation response experiment (Turk et al. 1980). At a comparable planting density, the 2-year average dry seed yield and seed size were similar for the two experiments. Our average pod

Table 2. Leaf analysis for cowpea grown at several soil salinities

Soil salinity ($\varkappa_e$)	Na	Cl	Ca	K	Mg	P
dS/m	mmol./kg dry wt					
			1980			
1.1	2.7	93	770	466	142	111
3.2	2.8	197	1010	373	140	100
4.3	2.5	194	965	391	152	95
6.9	2.7	281	1060	329	143	94
L.S.D. (0.05)	NS	74	NS	NS	NS	NS
			1981			
1.1	5.8	108	522	736	183	123
5.2	6.2	216	711	646	174	122
6.9	6.3	208	744	625	158	121
9.5	6.7	274	770	544	125	103
L.S.D. (0.05)	NS	72	100	88	NS	11

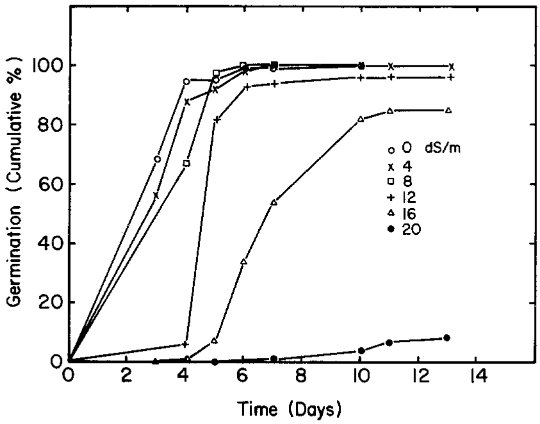

Fig. 2. Germination response of cowpea (cv California Blackeye No. 5) to six salinity levels

density (pods/m^2) was only 87% of the former experiment. Turk et al. (1980) found that seed yield, pod density and seed weight differed significantly between years even in adequately irrigated plots. Our data would support this conclusion, since all yield parameters except number of seeds per pod were higher in 1981 than in 1980.

Mineral analysis of leaves (Table 2) showed that Cl was the only ion that was significantly affected by salinity in both years. Although not significant, the change in concentration of the other ions in 1980 with increasing salinity followed the significant changes found in 1981. Leaf Ca and Cl increased, while K and P concentrations decreased with increasing salinity. Sodium was essentially excluded from leaves at all salinity levels, although the concentrations were slighly higher in 1981 than 1980. Magnesium, which did not change in 1980, tended to decrease with increasing salinity in 1981.

Chemical analysis of the dry seed that was harvested in 1980 showed that both Na and Cl were excluded from the seed with increasing salinity. None of the other ions showed any consistently significant changes with increasing salinity levels. Average mineral contents in the seed in mmol/kg weight were 5.0 Na, 3.8 Cl, 20.0 Ca, 80.1 Mg, 404 K, 177 P, and 67.6 S. Nitrogen content in the seed averaged 36.8 g/kg dry weight. Sodium and P were the only ions found at higher concentrations in the seed than in the leaves.

Seed germination showed two effects of increasing salinity in the germination medium (Fig. 2). At salinities up to 12 dS/m, there was a delay in germination but no significant reduction in final germination percentage. However, both 16 and 20 dS/m significantly ($P < 0.01$) reduced final germination percentage. Salts in the seed bed may cause osmotic or specific toxicity effects on germinating seeds that may result in reduced or retarded germination (Waisel 1972). The response obtained with cowpea up to 12 dS/m is similar to that shown for *Pisum sativum* L. (Manohar 1966) and may be considered to be purely an osmotic effect as germination was merely delayed. Reduced final germination at 16 and 20 dS/m may be an osmotic or toxic effect or a combination of both, although no tests were made using isoosmotic solutions of permeating and non-permeating solutes to test this point further.

Acknowledgement. The senior author wishes to thank the H. V. McKay Trust and the Ian Potter Foundation for partially supporting grants. The assistance of Donald Layfield in conducting the mineral analysis of the plant tissues is gratefully acknowledged.

References

Balasubramanian V, Sinha SK (1976) Effects of salt stress on growth, nodulation and nitrogen fixation in cowpea and mung beans. Physiol Plant 36:197

Brown JA, Jackson RK (1955) A note on the potentiometric determination of chloride. Proc. Am Soc Hort Sci 65:187

Hall AE, Dancette C (1978) Analysis of fallow-farming systems in semi-arid Africa using a model to simulate the hydrologic budget. Agron J 70:816

Imbamba SK (1973) Response of cowpeas to salinity and (2-chlorethyl) trimethyl-ammonium chloride (CCC). Physiol Plant 28:346

Kitson RE, Mellon MG (1944) Colorimetric determination of phosphorus as molybdivanado-phosphoric acid. Ind Eng Chem Anal Ed 16:379

Lush WM (1979) Aspects of the evolution of cowpeas (*Vigna unguiculata* (L.) Walp.). Ph. D. thesis. Australia National University, Canberra

Lush WM, Rawson HM (1979) Effects of domestication and region of origin on leaf gas exchange in cowpea (*Vigna unguiculata* (L.) Walp.) Photosynthetica 13:419

Maas EV, Hoffman GT (1977) Crop salt tolerance – current assessment. J Irrig and Drainage Division. Am Soc Civil Engrs 103:115

Manohar MS (1966) Effect of 'osmotic' systems on the germination of peas (*Pisum sativum* L.). Planta 71:81

Molnar I (1961) A Manual of Agriculture. Aust Inst of Agric Science

Rachie KO, Roberts LM (1974) Grain legumes of the lowland tropics. Adv Agron 26:1

Ravikovitch S, Porath A (1967) The effect of nutrients on the salt tolerance of crops. Plant Soil 26:47

Russell JS (1976) Comparative salt tolerance of some tropical and temperate legumes and tropical grasses. Aust J Exp Agric An Husb 16:103

Shaw WM (1959) Nitric perchloric acid oxidation for sulfur in plant and animal tissues. Agr Food Chem 12:843

Tawfic HA, Abo El-Saod IA, Maria AM (1977) Effect of salt concentrations on the growth and internal structure of cowpea plants. Ann Agric Sci 20:171

Turk KJ, Hall AE (1980a) Drought adaptation of cowpea. II. Influence of drought on plant water status and relations with seed yield. Agron J 72:421

Turk KJ, Hall AE (1980b) Drought adaptation in cowpea. III. Influence of drought on plant growth and relations with seed yield. Agron J 72:428

Turk KJ, Hall AE (1980c) Drought adaptation of cowpea. IV. Influence of drought on water use and relations with growth and seed yield. Agron J 72:434

Turk KJ, Hall AE, Asbell CW (1980) Drought adaptation of cowpea. I. Influence of drought on seed yield. Agron J 72:413

Waisel Y (1972) Biology of halophytes. Academic Press, New York and London.